HIGH SCHOOL STUDENTS' MODELS OF RELATIVE MOTION IN PHYSICS

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Abstract

The relative speed concept was chosen since it is linked with the relative nature of motion and it is likely that the students would harbor many alternative conceptions about it. The research objective was to identify the various ways students conceive relative motion. Qualitative data collected in various forms of representation received a categorization analysis. Several models of students' understanding about relative motion had been identified. Suggestions are offered to the classroom teacher to help his students understand relative motion.
Keywords: *relative motion, POE tasks, high school physics education, conceptual understanding*.

Introduction

The study of relative speed causes a lot of difficulties to students (Walsh, Dall'Alba, Bowden, Martin, Marton, Masters, Ramsden, & Stephanou, 1993). Hence, the difficulties encountered in trying to understand constant motion are compounded in the case of relative motion, such as pursuits of objects with parallel trajectories but with different speeds (Reif, 2008). Regarding the physical situations involving relative speed, the initial and final conditions of their travel must also be taken into consideration. Considering these issues, it is rather surprising that there are few studies that look into students' understanding of relative motion. Following these various considerations, the research aimed to identify the models students used when trying to predict properties of relative motion.

Conception of Activities

As regards the activities of conceptual understanding of relative motion phenomena, we used a concrete set-up. Moreover, we gave students an activity guide allowing them to work in small groups. To help their investigation, the guide proposed to students various activities (questions, graphics to draw, etc.) to guide their modelling process. This process was structured as a POE task (Prediction> Observation> Explanation). The POE task took place in the following way. First the teacher explained each physical situation with the help of concrete set-up placed in the center of the classroom so that

each one can see its various features. The teacher mentioned that students would have to predict what would happen to the motion if he was to perform the experiment described in the guide. He also told them that they had to draw the trajectories of the balls and answer the questions in the guide. Students were to proceed to this task individually. As such, while opening their guide, students could read the physical situation in the guide just described by their teacher and answer questions in the space provided in it. These questions asked the student to predict what would arrive if the experience was to be performed and to write their predictions in their notebook.

As for the relative motion, the guide described the situation in the following way. One gives a small impulse to the ball (A) in order that it rolls from one end to the other. The position of the ball A after 1 sec is given in the figure below (see figure 1).

Fig. 1

Figure 1. Ball B is rolling toward the right end of the track.

A few seconds later, a second ball (B) is pushed with an impulse larger than ball A on a rail parallel to the first (see Figure 2).

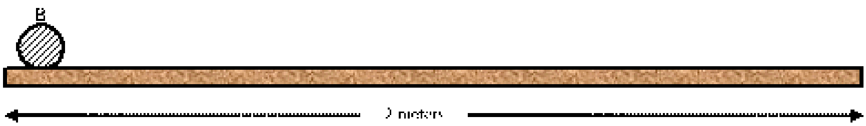

Figure 2. Ball B is launched in parallel track with a time delay.

The guide asked students to draw the expected positions of the ball (A) and the ball (B) in the seconds following the impulse. The position of the ball (A) at 1 second was already indicated. Important reminder: the ball (B) has been pushed with a certain delay relative to the ball (A) (say 2 s) but with a greater impulse. Following their prediction about trajectories of balls A and B, students were asked to write if, according to them, ball B would catch up on A and to explain their answers.

Research Methodology

The sample consisted of two classrooms of 21 and 24 students respectively. These two classrooms were following an optional introductory course in physics in the 11th grade at a high school in the province of Ontario in Canada. The first group was composed mainly of students who had chosen a special orientation toward science offered by the school so that it was reasonable to assume that they were interested in science in general and physics in particular. The second group was composed of regular students and a small number of students with learning disabilities. The teacher of the first group was of feminine gender and had five years of experience in teaching science. The teacher of the second group was of masculine gender and had twenty years of experience in teaching science and mathematics. Both teachers held bachelor's degree in science and a science teaching certificate.

During the experimentation, the main researcher or one of his research assistants were present at each of the periods to observe the unfolding of the events and collect students' answers to the questionnaires in the guide. This research implemented a qualitative case study approach for collecting and analyzing the data (Karsenti & Demers, 2011). In order to study the students' conceptions about relative motion, we analyzed the content of the activity guide students had to fill. Answers written by students in the guide were expressed in different ways: text when answering questions, iconic in sketches of the moving ball. Qualitative data collected in these various forms received a categorization analysis (Miles, Huberman, & Saldaña, 2014).

Research Results

Each student's answers were analyzed in the framework of a multiple-cases study (Yin, 2014). However, due to space limitations, this section presents only the principal students' models identified in this research. These models emerged from the analysis of students' predictions about the set-up presented to them by the teacher and before any experiment was done. Let us remember that the main task of students was to draw the position of both ball A and B on a graphic presented to them (see Figures 3 and 4) and to predict if ball B would catch up on ball A and to explain their answers.

With respect to the first student (St1), his prediction about the motion of ball A was that it undergoes a constant motion (which is evidenced by the constant spacing between adjacent time intervals) (see Figure 3). Similarly, he predicts constant motion for ball B but with longer spacing that reflects its greater speed. However, he does not mention the difference in initial conditions since ball B was launched with a time delay respectively to ball A (see figure 3). However, to the question about Ball B catching up on A, St1 wrote: "Ball A goes at a constant speed. Ball B is pushed one second later than ball A. The balls will meet between the 2nd and 3rd seconds. Ball B completes faster its journey."

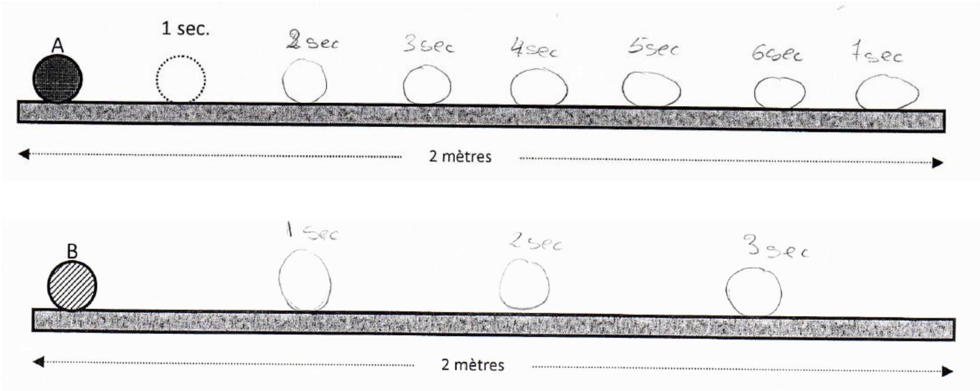

Figure 3. Prediction of St1 about the relative motion of balls A and B.

Other students' models have also been identified in a similar way. For example, the trajectories that student St2 drew for both balls A and B showed non uniform motion (see Figure 4).

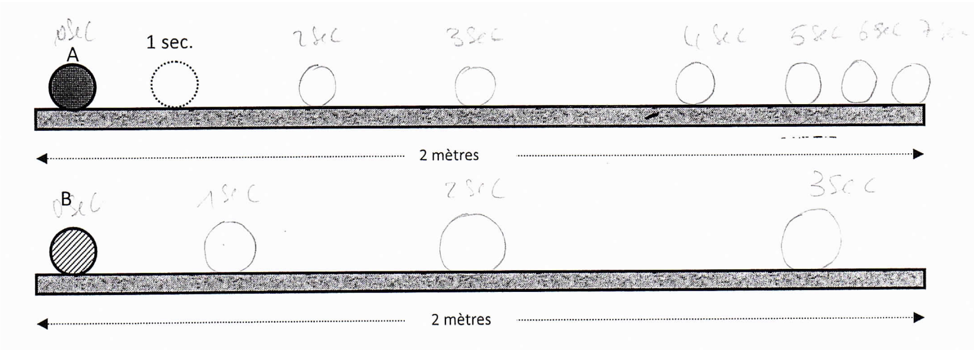

Figure 4. Prediction of St2 about relative motion of balls A and B.

More specifically, St2 student explained that the speed of ball A would increase in the first half of its trajectory and would slow down in the second half. Furthermore, St2 made the prediction that the speed of ball B would increase uniformly. St2 also predicted that ball B would eventually catch up with A since it was thrown with a higher speed. Table 1 below described the various models of relative motion identified.

Table 1. Students' models of relative motion.

	Trajectory of ball A	Trajectory of ball B	B catch-es up on A	Time de-lay	Time scales of A and B	# of students (%)
Model 1	Speed stays constant	Greater con-stant speed	Yes	No	Independent	18 (40 %)
Model 2	Speed stays constant	Greater con-stant speed	Yes	Yes	Independent	6 (13,3 %)
Model 3	Speed increases in first half and decreases in second half	Speed increases regularly	Yes	No	Independent	1 (2,2%)
Model 4	Speed stays constant in the first half and decreas-es in the second half	Speed stays constant	Yes	Yes	Independent	1 (2,2%)
Model 5	Speed stays constant in the first half then decreas-es in the second half	Speed increases regularly	Yes	No	Independent	1 (2,2%)
Model 6	Speed stays constant in the first half then decreas-es in the second half	Speed decreases regularly	Yes	No	Independent	1 (2,2%)
Model 7 (inter-me-diate)	Speed constant	Greater con-stant speed	Yes	Yes	Dependent	6 (13,3%)
Model 8 (scientific)	Speed constant	Greater con-stant speed	Yes	Yes	Dependent. (Use model for problem solving)	1 (2,2%)
Absent or insufficient information						10 (22 %)

Discussion

If one examines the results presented in table 1, there is one common ground that all students agreed upon: Ball B will eventually catch up on ball A, despite they harbor very different models about relative motion. Thus, except for the intermediate and scientific models (model 7 and 8 respectively), it appears that students study motion of balls A and B quite independently and that the main explanation of B catching up on A would be that ball B was launched with a higher speed than A. This explanation does not appear to depend on the time delay or on the specific trajectories of both ball A and B (whether it is uniform or non-uniform). Finally, there appear to be some contradiction between the trajectories drawn by students and their written answers. Thus, we could infer that these students may not have mastered how to transform their predictions into different modalities (trajectories, written statements).

In this respect, students may need to establish links between various factors that have an influence on the relative motion of balls A and B. Indeed, none of these students, to the exception of one (model 8: scientific model), seem to have reached the higher levels of understanding on the scale of Walsh et al. (1993). These higher levels consist of incorporating initial conditions (time delay, initial difference in positions) in their prediction) and furthermore, the establishment of a new entity, the relative speed (Walsh et al. (1993).

Conclusions

In order to improve the efficiency of POE tasks, it is important, according to the results of the present research, to consider the presence of students' models with respect to the specific situation of relative motion that comes under study. These models show that most students considered the motion of balls A and B quite independently. Moreover, the influence of initial conditions upon the relative motion of balls A and B were not well understood by students. Moreover, some students still clung to their naïve models of irregular motion (Trudel & Métioui, 2011), when predicting the horizontal motion of balls, compounding their difficulties. Using these results, a teacher may want to know how to help his students become aware of the influence of initial conditions upon the motion of the balls. In this case, this teacher may present his students supplementary cases where initial conditions, such as the time delay or the initial distance between A and B, are varied. Moreover, small group discussion among students while predicting and experimenting can help them compare and choose the best alternatives among predictions emitted by the members of their team.

Finally, this study has the advantage of showing us that speed comparison problems, and thus relative speed, may be of great complexity for students. Understanding the concept of relative speed may, among other goals, lead students to understand better the role of initial conditions in problem-solving in kinematics. This multiple-cases study involving only two classrooms cannot claim the generalization of results or transfer to the classroom. Future research should involve a more diversified sample of students as well as to cover more scientific disciplines.

References

Karsenti, T., & Demers, S. (2011). L'étude de cas [The case study]. In T. Karsenti & L. Savoie.-Zjac (Eds.), *La recherche en éducation: Étapes et approches* [Educational research: Stages and approaches], 3rd ed. (pp. 229-252). St-Laurent (Québec): ERPI.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook*, 3rd edition. Washington (DC): SAGE.

Reif, F. (2008). *Applying cognitive science to education: Thinking and learning in scientific and other complex domains*. Cambridge (MA): MIT Press.

Trudel, L., Métioui, A. (2012). Favoriser la compréhension des concepts du mouvement rectiligne à vitesse constante à l'aide d'une investigation scientifique assistée par ordinateur [Promoting a better understanding of linear motion at constant speed thanks to a computer-aided scientific investigation]. *Recherches en didactique des sciences et technologies*, *4*, 83-108. Retrieved from https://journals.openedition.org/rdst/494.

Walsh, E., Dall'Alba, E. G., Bowden, J., Martin, E., Marton, F., Masters, G., Ramsden, P., & Stephanou, A. (1993). Physics students' understanding of relative speed: A phenomenographic study. *Journal of Research in Science Teaching, 30*(9), 1133-1148.

Reif, F. (2008). *Applying cognitive science to education: Thinking and learning in scientific and other complex domains*. Cambridge (MA): MIT Press.

Yin, R. K. (2014). *Case study research: Design and methods*. Washington (DC): SAGE Publications.